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TECHNICAL REPORT ARLCD-TR-81031

EQUIPMENT FOR AUTOMATED LOADING AND ASSEMBLY OF MORTAR PROPELLING CHARGES M204 (60-MM) AND M205 (81-MM)

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M205 containers	Tab seal station	Height check
Automated equipment	Tab check station	Programmable Logic Controller

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report covers the design, build, and test of prototype automated equipment to load, assemble, and pack the mortar propelling charges M204 (60-mm) and M205 (81-mm). The system produces 108 increments per minute. It is a nonsynchronous system with nine individual stations which weigh the container and propellant, fill the container, form and seal the tab, check the seal and assembly weight, and carry out critical inspections. The system is coordinated by a programmable logic controller which also collects and retains critical data. The system is to be installed on the mortar increment line at the Milan Army Ammunition Plant.

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SUMMARY

This report covers the development of automated equipment to load, assemble, inspect, and (to a limited extent) pack the individual increments of mortar propelling charges M204 (60-mm) and M205 (81-mm). The line is a unique, high-volume production system that can produce mortar charge increments at the rate of 108 per minute. The important benefits of this system are: effecting of considerable cost savings through line personnel reduction, incorporation of extensive safety engineering into all operations, reduced exposure of line personnel to explosive components, and production of a highly reliable item. The line also permits initiation of production in a very short time, production of either charge by an expeditious tooling change and flexibility for change of tooling design to accommodate possible changes in charge increment weight, dimensions and configuration. The system is a nonsynchronous or power-and-free production system and is composed of separate stations with ancillary work areas. These stations and areas are:

1. The empty-weigh station, which automatically receives the empty increment or container, inspects and weighs it, and places it in a pallet for subsequent operations.

2. The propellant weigh-and-fill station, which automatically weighs and checkweighs the propellant and assures its complete deposition into the container.

3. The tab-seal station, which automatically cuts the tab, applies acetone, and seals the container pouring hole.

4. The tab-check station, which automatically stops the pallet, requires visual inspection for tab placement, and automatically releases the pallet.

5. The reject-removal station, which automatically stops a pallet with a rejected increment, removes the increment, and deposits same in the reject bin.

6. The final-weigh station which automatically weighs the propellant of each sealed increment (container weight tared), checks increment height again, and stamps the container assembly nomenclature, lot number, etc.

7. The inspection table and belt conveyor subsystem which receives filled and sealed increments from the final-weigh station, conveys the increments to the inspectors, and then conveys the acceptable increments (placed on packing trays) to the packing area.

8. The packing area, which is composed of a packing table (manual packing), roller conveyors, a load balancer pickup unit and guide system for placing the taped inner fiberboard box (packed with trays of increments) into an aluminum foil barrier bag and then (after heat sealing of the barrier bag) placing the sealed box in the outer fiberboard box.

9. A pallet-cleaning area (if required), which will remove any loose propellant grains that might have fallen on the pallet.

The principal portion of the system is composed of two separate, concentric carousel conveyors with the independent production stations located in between. The stations produce at different production rates; therefore, one or more duplicates are required to balance each type operation for the production level chosen. Each of the pallets carries one increment, and approximately 300 of these are employed to meet the production rate of 108 increments per minute. The empty and final-weigh stations employ the walking-beam principle and, respectively, place and remove the increment in/from the pallet. The increment is locked in the pallet during most of the work. The pallet moves from one conveyor into a station (which is calling for work), and the pallet is ejected onto the second conveyor which propels it via the frictional force of a flat top chain to the next operation. Here, the pallet moves into the station in the opposite direction and back to the first conveyor after completion of the new operation.

The system represents a significant advancement in the state-of-the-art of automated U.S. Army item production. The following are some of the important features of the system:

1. The incorporation of an accurate, stable, beamless force-restoration scale in the empty and final weigh stations.

2. The use of a programmable logic controller (PLC) to control operation of the line and each station and to effect 100% checkweighing of the propellant (when in the sealed container) in the final-weigh station.

3. The implementation of a system which permits production on a highly economical basis at rates varying from 25 to 108 (and potentially greater) increments per minute.

4. The use of independent stations integrated with a nonsynchronous transport system which permits optimum pallet floats between operations and eliminates a mix of processed and unprocessed increments at all stages of manufacture.

5. The integration of inspections and process controls to assure production of an acceptable item, the elimination of any unsafe conditions or unnecessary maintenance, and the accommodation of product dimensional and physical deviations wherever possible.

Currently, the prototype system, consisting of one each of the above stations, is being modified at Innova, Inc., Clearwater, Florida to effect certain final improvements prior to its shipment to Milan Army Ammunition Plant (MAAP), Milan, Tennessee. Acceptance runs with M10 propellant will be completed at MAAP by the Fourth Quarter FY 81. MAAP will implement its modernization project 5802007 on completion of these acceptance runs.

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INTRODUCTION

This project was initiated contractually in the Second Quarter of Fiscal Year 1976; Contract DAAA21-76-C-0183 was awarded to Innova, Inc., Clearwater, Florida, on 25 March 1976. The purpose of this contract was to design, build, and test an automated system to load, assemble, inspect, and (to a limited extent) pack the individual increments for mortar propelling charges M204 (60-mm) and M205 (81-mm). Plans to commence this project earlier had been delayed several times due to product development problems and design changes. Changes in the physical characteristics and deviations in the dimensions which were encountered in the manufacture of Government-furnished containers also caused delays and problems in subsequent equipment design and debug runs.

The Innova contract was initially funded only for phase I, "Concept and Design," with FY 75-76 authorization. This design work was completed in July 1978. The original schedule for this phase had been extended at the request of the contractor without impact on the overall program schedule since funds for phase II, "Build and Test," were not available in FY 77. The powder-weigh-and-fill station was built with remaining FY 76 funds and was completed in October 1978. The remaining portion of the line was built and tested with FY 78 authorization; the contract was amended for this work in July 1978.

The FY 78 authorization was supplemented on two occasions: (1) to manufacture a test quantity of containers (production items not available) and (2) to supplement the contract due to cost increase of overhead or direct labor and the need to modify certain stations. Building and testing of the system was completed in July 1980.

The principal benefits expected over past handlines and mostly achieved from th automated system were: reduction in line personnel from 40 to 14, improved safety, reduction of personnel exposure to explosives, improvement of product reliability, reduction of production lead time, and production of multiple products. The above benefits also apply to a major degree in the major interim line at Indiana AAP installed under project 5783006. The new Innova line design will be available for modernization and for expansion of other GOCO plants, such as Lone Star AAP and Kansas AAP.

Economical production, both in low capital investment and reduced line personnel use, has been a primary objective of this project. Of equal importance in design of the system is safety of line and maintenance personnel, both with regard to explosive handling and concentration and with regard to equipment operation. Hazards analyses have been run to effect the required safety. Other important considerations have been to design the equipment to handle and provide latitude for change of tooling design to accommodate product design and configuration changes in the future. Development and history of the system and station designs follow.

SYSTEM DESCRIPTION

This fully automated load and assembly system weighs and loads the propellant into the container, seals the pouring hole, weighs the assembly, marks the sealed container with the appropriate identification and performs certain very important inspections. The system also includes the equipment for visual inspection and hand packing of the increments. The packaging for the increments has been designed for automated handling and packing. However, this project covers only hand packing and assist-equipment.

The system consists of a nonsynchronous or power-and-free system with six different stations. These stations are, in the order of use, the empty-weigh, propellant-weigh-and-fill, tab-seal, tab-check (visual), reject-removal, final-weigh (includes marking). The completed increments are inspected after being deposited from the final-weigh station onto the moving belt (for inspection) of a unitized table and belt conveyor subsystem. A roller conveyor supports the fiberboard boxes into which the inspected increments are placed. A load balancer is used to place the inner box into the aluminum foil barrier bag and, after heat sealing of the barrier bag (vacuum shrunk onto the box), this initial packaged assembly is placed into the outer fiberboard box. The latter box is sealed shut with tape and marked with the appropriate identifying nomenclature. This final package is then palletized for shipment.

The anticipated production rate of a complete system is 108 assembled increments per minute. This production is accomplished by installation of multiples of the different types of stations on the pallet conveyor subsystem. The pallets have one container in each and are driven by the frictional force between the pallet and moving, flat-top chain. A pallet is automatically stopped next to a station calling for work, ejected into the station, and locked in place; then the work on the increment is performed. The pallets move from one conveyor to another, stopping in between to have work done on the increment. To meet the production rate of 108 increments per minute, approximately 300 pallets will be required.

In the first station (empty-weigh) and the last type station (final-weigh), work is done on the increment by means of the walking-beam principle. In the four central stations all work is performed on the container locked in position in the pallet. The anticipated production rate (as opposed to the design rate of 128 assembled increments per minute) is an actual expected output when the efficiency of the system is considered; it is also the rate which will adequately support the complete round line at MAAP, which will produce at a rate of 27 increments per minute.

The control system used in the line is relatively complex. Although electrical controls are predominantly used, pneumatic controls are also employed, but to a lesser extent. Pneumatic controls have long been used in automated or semiautomated ammunition processing equipment due to their inherent safety features. Because of the high production rate required (108 increments per minute) and in order to obtain an acceptable mean time between failures (MTBF), stations with relatively high cycle rates were designed. Accordingly, electrical controls were used wherever required to reduce the use of relays, switches, and other

mechanical devices. These controls were explosion-proof or intrinsically safe electrical controls.

Solid-state photocells using light-emitting-diode (LED) light sources, output relays, and microprocessor-based devices -- all with long life -- were selected. For instance, the Allen-Bradley Programmable Logic Controller (PLC) 1771-L3, which performs arithmetic functions and controls line operations, was selected because it replaced several hundred relays and because of its extremely low failure rate. This controller receives input signals from limit switches, photocells, and other sensors and then provides output signals to solenoids and indicator lights, thereby controlling the sequence of operation and providing the status to the control room of all stations. In the full production line, two PLC's will be used. One will control the three each empty- and final-weigh stations (including the arithmetic, identification, storage, and calculations of the propellant weights). The second PLC will control the rest of the line operation.

All stations were designed and built as complete integral units and are shipped fully assembled. Each station contains an explosion-proof junction box which contains all the wiring of the station. The only wiring or conduits required at the GOCO plant is between the junction box and the appropriate equipment in the control room, between the equipment in the control room, and between the stations on the line. Each station contains a manual control panel to operate the various individual functions by the operator at the station. The panel is provided for maintenance and setup and contains the controls to sequence the station through its specific operations. The stations are not designed to be operated manually under automated or under certain fault conditions.

Temperature and humidity control is required for the line. This control is required for the scales and for the propellant to reduce the effect of temperature and humidity variation on the propellant weight. The temperature and humidity controls to be used are ±2.2°C (±4°F) and 60% to 70% relative humidity (RH). The RH control also eliminates any electrostatic charge buildup. This air-conditioning is also required for the control room where an operator and high-heat-source electronic equipment are located.

STATION AND ACCESSORY DESIGN

Overall Functioning of System

The increments are manually unloaded from the cartons and packing trays by an operator. The operator strips the increments from the tray directly onto a vertical mandrel of one (of three or four) empty-weigh station. The increment is automatically fed through the station (increment orientation and height are checked and the weight is stored in PLC). Acceptable increments are placed into a waiting pallet and those rejected are ejected into reject bins in the station itself. The proper positioning of the increment in the pallet is checked by a photocell and LED setup; if the increment is properly seated and locked in the pallet, a memory pin or flag is pulled up, indicating a good increment. The pallet then proceeds to the powder-weigh-and-fill and tab-seal stations. The

pallet is automatically stopped next to the first station of this group calling for work and is ejected sideways into the station.

The increment is filled with propellant, and the pallet moves approximately 152 mm (6 in.) to the tab-seal station where the tab is applied to the increment. If the increment is not filled properly or if it cannot be filled, the flag is pressed down to the fault position, the tab is not applied to the increment, and the pallet is ejected to the other conveyor and proceeds to the tab-check station. If the increment is filled properly, the flag remains in the up position and the tab is applied. The pallet is ejected and then moved to the tab-check station; it is stopped and moved sideways into the first tab-check station calling for work. If the flag is up (good increment), the pallet is automatically stopped in the station; on completion of the inspection by the inspector, the pallet is automatically released. If the flag is down (rejected increment), the pallet stays in the outer conveyor track and proceeds to the reject removal station. All good pallets from the tab-check station proceed through the reject-removal station (directly over coveyor; i.e., no sideways movement of pallet is required) without stopping at the final-weigh station. The filled and sealed increment is removed from the pallet and work is done in the final-weigh station. Good increments are placed on the output belt conveyor for inspection and packing. Bad increments are rejected into reject bins in the station.

The movement of the pallets (approximately 300) down a conveyor or track and in and out of a station is controlled by conditions ahead of the pallet. For instance, a pallet will not be ejected from a station if another pallet on the conveyor is passing or about to pass the station exit; a waiting pallet will not be ejected into a station if another pallet is in it or is still leaving it; and a pallet will stop or queue if another pallet is leaving or just starting to move out of station. This control is required on both parallel conveyors due to the entering and leaving action of the pallets relative to the stations.

The locking of the pallets into the stations, the sequence of operations within each station on the line, and the release of the pallets are controlled by the PLC controller. PLC outputs energize explosion-proof solenoids of stations, and these solenoids actuate power valves, which position the power cylinders for performance of specific operations.

Successive switch functions are made as the sequential operations in a station occur. If a cylinder or operation fails, the corresponding switch function is not made and the station shuts down. Each station on the line has a fault panel in the control room. The specific cylinder failure is immediately illuminated on the panel. This indicator, as well as the associated annunciator, will remain on until an operator or maintenance person resets the fault control at the station. Equipment availability is greatly enhanced by this rapid, direct-fault identification. Each station panel in the control room also permits pushbutton control of that station.

Both the manual control panel at the station and the control panel in the control room for that particular station include an "Auto/Manual" switch for selection of the mode of operation. A dual-locking feature has been incorporated for the safety of the station operator, which permits operation only by him when

the station is in the manual mode. When the station is in the automatic mode, the console operator in the control room can start the station. The switches on the master power panel in the control room control the electrical power to the line. From this panel, power can be applied to or cut off from all stations at once or to each station individually by its respective switch. When the individual station stop button is pushed or when the control panel stop button is pushed, each station completes its cycle. Each station or the system is stopped immediately in the control room by actuation of the appropriate "Power Off" or "Emergency Stop" button, or by pulling of the emergency stop cord at the line. In this emergency stop situation, each station stops immediately or anywhere in its cycle and, after the problem is corrected, the stations must be manually operated to complete their cycle, in readiness for automated operation.

Each station has its own control panel for manual check or startup of station after correction of its or other station line fault(s). Two other controls which facilitate identification of an imminent or existing problem on any station are the counters, both at the station and in the control room (slow down of station indicated if count is low), and an automatic control that closes each station down after three consecutive rejects.

After the last operation, the good increments are placed on a unitized dual belt and table for inspection of each increment, placement on a packing tray, and then placing of this filled tray on the second or back belt for transport to the packout area. In the packout area, the filled trays are placed into an inner fiberboard box in multiple layers, the box is sealed and, with the aid of a load balancer, is placed into an aluminum barrier bag which is shrunk and sealed over the box. Finally, the load balancer places this moisture-proofed box into an outer fiberboard box.

The operation, special design features, and development background of each station is described below.

Empty-Weigh Station

In the final design, containers are manually loaded onto the input mandrel of the empty-weigh station. This mandrel automatically powers the containers to the bottom position, where they are loaded onto a platen and transferred into the station. The station is a six-stage walking beam which is cam-driven to assure proper timing. At the first stage, the container is taken from the platen and placed onto the hole probe stage. Here a gage is lowered to check that the container is properly oriented. After the hole-check is completed, the containers are transferred to the height-check stage (next cycle).

If the hole probe is bad, the platen at the height-check stage is open and the container is rejected. If the hole probe is good, the container is placed onto the platen and the height is subsequently checked. After height-check the container is transferred to a platen for rejection or retention: if the container is good, it is retained on that platen; and, if not, it is rejected.

The next stage is for weighing of the part. The container is placed onto the scale pan and the weight is recorded within the Allen-Bradley 1771-L3-PLC

controller for subsequent use. If the weight is bad, the next transfer allows the container to be rejected. If the weight is good, the container is retained at the next stage.

The next cycle brings this increment to the pallet. The pallet, which is stopped, has its identity read and the previously recorded weight is then stored within the controller at an address associated with that pallet identity. The container is then placed into the pallet. The container is checked automatically (electric eye) to assure it is properly placed, and, if so, the flag is pulled up to indicate that the container is good. If the container is not properly placed, the flag is not pulled up, and the pallet proceeds around the system on the outer conveyor to the reject-removal station, where is it is removed.

The empty-weigh station, in addition to having normal intrinsically safe photocells to perform sensing operations, also contain 10-photocell array to read the pallet identity while the pallet is stopped at a station. The pallet identity mechanism consists of nine bits of data for binary identification and one bit for parity check. The pallet identity mechanism consists of retroreflective tape incorporating a pattern to allow the reading of various 1's and 0's. A group of 10 fiber optic tubes in one bundle will be molded by Dolan-Jenner Corporation of Massachusetts and will be placed alongside the pallet in the station to read the pallet identity when the pallet is stopped. This fiber optic bundle will go back to light sources and receivers located in an explosion-proof box at the station. Cables from this box will be routed back to the control room amplifiers and output devices for use with the PLC.

Container orientation is maintained through the design of the pickup fingers and the design of the platens. The pickup fingers grasp the part positively before the part is moved so that prior orientation is not disturbed. When the container is released, it rests on a platen with a shaped guide to reorientate the part from any position. The container is always positively handled to assure position control. In the pallet the container is inserted over a central locator, onto three support blocks, and then against three vertical stop blocks. When the container is released from the holding device, a spring-loaded locator on the pallet applies slight pressure to the container to seat it against the stop blocks, thereby accurately locating the increment.

All containers which fail hole-probe, height-check, or weight-check are separately rejected and segregated within the station. Three separate reject bins are provided at the station for accumulation and easy removal of the rejects. The design of the bins is based on ARRADCOM safety tests and provides for safe accumulation (no detonation) of containers. Sensors to detect the level of containers in the bins can be installed; however, since accumulation of reject quantities is expected to be small, periodic emptying of all line reject bins once or twice a day by a worker will possibly be adequate. This assumption will be checked further in large-quantity production runs.

The station contains a force-restoration balance for weighing the containers. Periodic calibrations are automatically performed (no personnel required) to assure that the balance is functioning properly during operation and whenever power is applied to the station. The acceptable tolerance of the calibration weight reading is ±10 mg, well within the tolerance limits of the container. The

scale is mounted on a separate pedestal from the station to assure vibration is isolated from station operations.

In the early development and design phase, the line concept consisted of a two-level conveyor system with a Geneva mechanism, leak-test stations, empty-weigh stations, fill stations, seal stations, tab-check stations, final-weigh, height-check, and marking stations and semi-automatic carton unload and loading system. System control was through a PLC and each empty container was identified as one of four weight lots by an appropriate flag set on the pallet.

One of the first changes consisted of changing the weight zones to actual container weights stored in a computer. The problem was that the tolerance of the empty container weight could mask a deficiency in the propellant weight and it would be necessary, therefore, to reject up to 60% of marginal containers and propellant weights to assure acceptable increments. This procedure was considered unacceptable, and it was decided to use a computer to record the weight of each individual container, the propellant weight, and the total weight.

The second change consisted of replacing the two-level conveyor system with a single-level system. Originally, increments were transported on the upper conveyor, and pallets were transported on the lower level. With the single-level system, the increments would be placed in the pallets at the Geneva mechanism, thereby eliminating any possible abrasion of the increment. Also, the two-level system had potential maintainability difficulties due to the proximity of the conveyors, which were separated from each other by a vertical distance of only 127 mm (5 in.). The single-level system resulted in simpler increment transfer (and lower cost) at the weigh stations, but added a pallet transfer mechanism (higher cost) to the leak-test stations. Analysis showed that the same quantity of leak-test stations would be retained, so the only penalty was the additional cost for the pallet transfer mechanism. This additional cost was offset by the conveyor savings; and a total system cost savings, as well as improved reliability and maintainability, was realized with the single-level conveyor system.

Shortly after the above changes, it was decided to remove the leak-test stations (for container) from the line. This decision was based on several factors; namely, that the standards for differentiating a nonleaker from a leaker that had not been established, indication at the time was that a seam leaker masked a body or nitrocellulose (NC) material leaker (establishment of above standards made more difficult) and decision that this test should be accomplished by the container manufacturer and/or on a sampling basis (and therefore separate from the line) at the GOCO plant. It was also decided to change the semi-automatic unpack-and-feed system for the container to a manual operation for reasons of the container configuration (integral tab) and dimensional variations, problems expected therefore in the above unpacking system and increased cost of developing a new system.

Removal of the leak-test stations left only the empty-weigh stations where the container would have to be removed from the pallet for testing and then be returned. Since the weigh stations were similar in quantity to the Geneva assemblies, it was decided to combine them into one station, similar in design to the final-weigh station. Also, the hole- and height-check stages were added to this walking-beam station. These latter two inspections were added for obvious

reasons of assuring that crushed containers or containers with the hole side downward were not taking up valuable space in pallets, thereby reducing the efficiency of the system.

Powder-Weigh-and-Fill and Tab-Seal Stations

The description and development background for these two stations are combined because they are essentially integral or side by side [pallet only moves 152 mm (6 in.) from one operation to the other]. In the design finalized for the powder-weigh-and-fill station, bulk propellant is fed to this station through a conveyor feed system supplied by MAAP. Any control of this infeed conveyor for the hopper (sensors in the feed hopper) will be incorporated by MAAP. The increment feed system used for feeding powder to the fill portion of this station is a modified X-174 system provided by Hi-Speed, Inc. This system accepts bulk propellant into the supply hopper and dispenses, weighs, and checkweighs the propellant to assure that it is the proper weight. All reject charges are automatically rejected from the feed system.

This system supplies an electrical signal to the fill station when a propellant charge is ready to be dispensed into the receiving funnel in the station. An electrical signal is also provided by the station to the Hi-Speed system to indicate readiness for another propellant charge. Our increment filling system, for placing the powder into the increment, consists of dual pinch valves and air pressure source. The upper pinch valve is normally open, and the lower pinch valve is normally closed. When propellant is received from the Hi-Speed system and the station is ready to fill the container, the upper pinch valve closes and the lower pinch valve opens. Additionally, pressure is applied to a chamber to blow the propellant into the container.

As the pallet enters the station for container filling, it is registered in place by a cylinder-actuated mechanism. This registry accurately locates the pallet horizontally and vertically. When the pallet is registered, a signal is given to lower the funnel into the hole. If the funnel does not enter the hole properly, filling does not occur. If no container is present, the funnel sensors so indicate (funnel goes down too far), and once again no filling takes place.

When the funnel enters the container hole properly, the appropriate air sensor is closed, and the filling process is started. Air is supplied and the propellant is injected into the container. A clear plastic window in the lower portion of the funnel is used in conjunction with a photocell to indicate when propellant is present and is removed from the funnel. At completion of filling, if propellant is still present in the funnel, the station is shut down, the increment is not removed, and the funnel remains lowered. An operator must clear the station and remove the propellant from the funnel. This precaution is included to prevent loss of propellant from the funnel onto the pallet if the funnel is not emptied. If the funnel is properly emptied (i.e., no blockage) the funnel is raised and the pallet is released.

The pallet is then transferred to the next position within the integral station for the tab-sealing operation. When the pallet is completely registered, tab material is advanced, cut, and wetted with acetone and then the tab is placed

onto the increment. The area around the increment hole is also wetted with acetone. Vacuum is used to hold the tab in place while it is being moved from the cutting position to the place where it is wetted and placed onto the increment. After the mechanism lowers the tab onto the increment, the vacuum is removed and air pressure is applied to force the tab onto the increment. The sealing and filling functions are combined in one station to keep to a minimum any possible loss of propellant during pallet transport.

During the early development phase, the combining of the powder-weigh-and-fill and tab-seal stations was decided at the same time as the decisions were made to eliminate the leak-test station and to combine the empty-weigh station with the Geneva Assembly system. Also, at this time, it was decided to replace the originally proposed mini-computer (which was to be used only to store and check the weights of the individual empty increment, the propellant, and the filled and sealed container) with the Allen-Bradley PLC. The Allen-Bradley PLC also has arithmetic capabilities but, additionally important, it would replace highly quantitative, costly, electric, pneumatic relay logic. The use of the PLC also assured compliance with MTBF reliability requirement of 4.75 hours (min). All of the above line and control changes resulted in a system with considerably less complexity and cost and with improved reliability and maintainability.

The original plan proposed for feeding powder was to use a coarse and fine vibratory feeder, to dispense the powder onto a force-restoration balance, and to use the near continual weight output to control "on" time of the feeders. This method is similar to the Hi-Speed scale approach. However, since the Hi-Speed scale has a 2-second weigh-and-calibrate cycle and since the force-restoration balance could have a complete cycle of as low as 0.2 seconds, the contractor proposed the use of this equipment, with the intention of reducing the quantity of required powder-weigh-and-fill stations for the complete system. As the design of the balance progressed, it became evident that the weight output was not sufficiently continuous as controlled by the discrete intervals established by the selected integration time. These discrete outputs were not adaptable to the continuous-feed system since the target weight could be reached between outputs, resulting in an overweight charge.

The design approach was then shifted to the feeding of powder for a set amount of time and then to the weighing of powder. Considerable tests using various feeder tray designs and timers provided results that were not sufficiently constant for use within this system. As a result, the use of the Hi-Speed feeder system for providing powder to the station was recommended. Accordingly, the Hi-Speed system, modified for the required production rates and propellant weight accuracies, was adapted for the prototype fill station.

Considerable problems were encountered in the design of the propellant-filling system. The problems basically involved the effect of the dimensions, dimensional deviations, and physical characteristics of the NC increment.

Propellant fill tests were run on increments with a hole of 4.7 mm (0.187 in.) diameter. These tests showed that the container could be filled in approximately 1 second with 13.8 kPa (2 psi) pressure applied to the top of the fill funnel. The tests also showed that a minimum funnel opening of 3.2 mm (0.125 in.) diameter and a maximum total internal angle of 15 degrees are required to

prevent bridging of the propellant within the funnel. To accommodate the 0.125-inch funnel opening, to allow reasonable funnel wall thickness, and to provide an adequate locating range of the funnel within the hole, the increment was modified to provide a minimum hole of 5.6 mm (0.220 in.) diameter.

Initial containers furnished by the contractor's supplier, Lory Industries, Inc., were acceptable for equipment design and debug purposes; however, compliance with container dimensional requirements was still required. As larger quantities of containers M204 were furnished, the dimensional problem continued. These product and machine problems also persisted with most of the other stations.

Attempts to use these deviating parts by modifying the tooling were partially successful, but improvement in the product dimensional control was still required. This station and the other stations would accept deviating containers to a considerable degree. However, certain dimensions were important for an efficient and reliable operating system; namely, the hole location, the open gap dimensional control and the inner diameter. These product dimensional problems are to some extent considered inherent in a relatively flexible plastic part such as the containers M204 and M205. Also, the quantities furnished were from the first large-volume production of the item and, more significantly, from a hand-line with minimum assembly fixtures.

A physical characteristic change occurred in the product during an ongoing ballistic investigation, which resulted in problems in the filling operation. (The investigation was to resolve the problems of unburned container material remaining in mortar tube, low velocity levels, and nonuniform firing results.) This problem was a decrease in the NC material porosity. Since the station filling operation was dependent on a certain minimum porosity level of the container [air pressure of 13.8 kPa (2 psi) used to rapidly move the propellant into the container], this lower porosity level caused low propellant weight fills.

This problem was corrected by redesigning the constant pressure loading system to a more complex jet and pulse system, not dependent on the container porosity level. This new propellant loading system fills the container at a slower rate, approximately one-third of the previous rate of 16 containers per minute.

In the integral tab-seal station, problems were encountered. These problems were both product and equipment oriented. For economy and automation purposes, it was decided early in the program to go with the tab strip or roll approach. Here, the tab roll has to be fed, cut to prescribed length, wet with acetone, and applied over the container opening. The drawings for the tab essentially required the tab to be cut or stamped from the same NC sheet material that is used to make the container and required that the tab be the same thickness as the container.

Purchase of the tab in the roll form was permitted; however, requirements for automatic feed had to be developed. After considerable effort by Lory Industries, Inc., and trial-and-error on the station, the process and product parameters were established. Some stiffness was required for automated feed purposes, but the required acetone absorption rate (1 1/2 sec approx.) limited the

stiffness. This stiffness was accomplished by Lory Industries, Inc., by the use of certain process controls. A special technique also was developed to attach sections of the strip material to arrive at the roll size of 254 mm (10 in.) outer diameter or approximately 61 meters (200 ft) of strip material.

Innova, Inc., also during this time developed tooling for cutting and feeding the tab strip material. Too stiff or too hard tab roll material did not feed as precisely as required and shifted or became skewed on cutting, resulting in problems of placement on the container hole.

The data that evolved finally indicated that the strip material parameters can vary for a particular tool design or setting and that availability of slightly modified tooling will accommodate even larger variation in the strip material. The acetone wetting characteristics of the strip material will, however, restrict this variation. Too soft or not sufficiently stiff material will not absorb enough acetone, even at twice the current 1 1/2 second wetting time (i.e., tab will not adhere to the container); and too hard or stiff material will not absorb enough acetone and, therefore, will not adhere to the container.

Acetone spraying of the increment and tab was considered as a means to seal the increment. Several companies (DeVilbiss, Binks, Graco, and others) were contacted relative to supplying necessary equipment, but they all felt that the spraying areas were too small and that the spraying duration was too short to allow controlled and repeatable volumes of acetone to be applied.

Various methods were considered for cutting the tab. Cutting of the tab, both wet and dry, was tested using different types of punch designs. A dry tab could be cut more precisely and cleaner than a wet tab. However, the wet tab tended to bend, smear, and leave large quantities of uncut fibers, regardless of the type of punch utilized. A scissor-type punch was found to give the cleanest, most precise cut. As a result of these tests, the tab-seal station incorporates a scissor-type punch to cut dry tabs from a reel of NC strip material.

Some problems were encountered in the tab placement over the container hole. The same shifting that occurred with stiff or hard tab strip material was also encountered when the material was too soft due to the fact that occasionally all the fibers free on the surface or matted in the NC matrix were not cut. Both of the cutting problems were resolved by controlling the process at Lory Industries, Inc., thereby also controlling the limits of hardness and softness of the strip material.

Problems were also encountered in attaching the tab securely to the container due to the considerable slope of the hole flange area. The preciseness of placement of the tab on the hole permits very little universal action in the head of the station. This problem was resolved by changing the head pickup vacuum to a blow-on method.

Tab-Check Station

This station is for visual inspection of the proper placement of the tab on the container hole. The inspector will inspect the filled and/or sealed

container to determine if: the tab covers the hole completely, no tab edge is raised or if edge is not adhering, tab is punctured, and loose propellant is on or adhering to the container or the tab. The inspector presses a "no" or "yes" (reject) button. If the "yes" button is pressed, the fault pin and the pallet are pressed down for removal at the reject-removal staton. The stopping, locking-in, and release of the pallet is automatically controlled by the PLC.

In the early design and building phase of this project, this station was completely automatic. Inspection was based on the height of the tab (i.e. , its thickness) over the hole flange area. A very sensitive multiple pin, depth-gage head (manufactured by Wallee Company) determined if tab was placed over the hole properly by determining if the four sides of the tab were located in the prescribed area around the hole. The drop or elevations of one of four pins of the Wallee gage would signify the tab's misplacement and, therefore, rejection of the increment. However, this technique had to be discarded (and replaced by the above visual inspection) when it became evident that the slope of the hole area, which established the slope of the placed tab, could not be controlled in the Lory handline.

Other automated techniques for this inspection separate from this project will be surveyed and one technique adopted in the near future.

Reject-Removal Station

Increments improperly placed in the pallet at the empty-weigh station cause the flag to remain down, and faulty increments generated at the powder-fill station cause the flag to be set in down position on the pallet. These pallets are sensed by the PLC and are stopped at the reject-removal station, where the increment is rejected. An air-jet device (tube) is used for this removal. Air pressure is applied to the tube and a coanda effect is generated to produce a vacuum and to lift the increment out of the pallet. The increment is withdrawn into the U-shaped tube and is deposited into a reject bin.

Two photocells on the down side of the tube and at the same height but 90° to one another are used to monitor the tube and to assure that the increment has been removed from the pallet. The two photocells are required to assure that passage of the increment will be detected, no matter what its attitude or profile orientation to the photocell sensing beam. Also, actuation of either of these photocells will cause the PLC to release the pallet from this station. If, for some reason, the increment is not removed (i.e., the photocell actuation does not occur) this fact would indicate that the increment has fallen back into the pallet and must be removed by hand. In such case, the pallet will not be released (indicated also in the control room on its panel) until corrective action has been completed. Every pallet with its flag down will be stopped in this station, and the rejected increment must be removed before the pallet is released. A pallet with the flag up or in acceptable increment position will just go through this station.

Increments with no tab will be removed without spilling of the propellant. Only one reject station is required for the full line. This station operates at approximately 28 increments per minute, and operates directly over the conveyor

(i.e., no side movement of the pallet is required). The exit of the rejected increment into the reject bin is controlled (in this and all stations) so as not to damage the increment; the preponderance of these increments will be suitable for special processing and subsequent hand assembly.

Final-Weigh Station

All pallets with the flag set up are stopped at this station. The increment is removed with a walking beam, cam-driven arrangement similar to that used in the empty-weigh station. After the increment is removed from the pallet, it is placed onto the scale. Pallet identity is read, and the weight is also recorded. Then the PLC calls up the empty weight stored for that pallet and subtracts the empty weight from the filled weight, determining if the charge is acceptable.

If the increment is acceptable, it is transferred to the height-check station, where the increment is checked to assure that no deformation has occurred. (If the increment was rejected due to the weight, it is still transferred to the height-check position, but the height-check platen is open and the increment is rejected.) After height-check, the next cycle places the increment on the marking platen. If the height-check was bad, the platen is opened and the increment is rejected. If good, the increment is stamped and placed onto the inspection conveyor.

The final-weigh station is also interfaced with the inspection conveyor in such a way that if a buildup of increments occurs on the conveyor, the final-weigh station goes down.

This station contains the same intrinsically safe photocell combination described for the empty-weigh station.

Packout

Five or six inspectors (depending on workload) will be seated at the output belt conveyor and table assembly for the production system. These inspectors remove increments from the conveyors in front of them; inspect the increments for shape, cracks, dirt, seam continuity, tab adhesion and orientation, and marking; and load them onto the packing trays. Based on an output production rate of 108 60-mm increments per minute, the workload for the inspectors is approximately 18 increments per minute.

When a tray is fully loaded by an inspector, he places it onto the conveyor. The trays are transported to a stop at the end of the conveyor, where they are loaded by another operator into the inner carton. This carton is on a roller conveyor which is 610 mm (24 in.) above the floor. When this operator places the carton on this conveyor, the operator also places the trays' flat and bar spacers and fillers in the carton and then seals the carton after it is filled. A portable hand tape dispenser is provided for sealing the carton.

After the carton is sealed, it is pushed a few feet along the roller conveyor, where another operator takes over. This operator will have placed an empty

barrier bag onto the support frame, having it ready for insertion of the inner carton. The operator then maneuvers the load balancer pickup clamps over the inner carton, clamps it, lifts it, and lowers it into the barrier bag. The load balancer is a Balance Master 150 Series industrial manipulator that gives near weightless, 3-dimensional maneuverablility to heavy loads. It is completely air operated, with no electricity or hydraulic pumps required. A pistol grip metering valve provides infinitely variable speed control. No adjustments are required for different load weights.

When the carton is properly placed in the barrier bag and the load balancer is moved away, the same operator removes the upper portion of the barrier bag from around the support frame. The operator places the open ends of the bag together and readies them for insertion into the barrier bag heat sealer and evacuator. The heat sealer has its own adjustable speed drive conveyor, so the operator needs only to guide the bag opening into the sealer. The heat sealer then guides and seals the bag automatically. Prior to guiding the bag into the sealer, the operator must place the vacuum evacuator nozzle into the bag opening. The operator then guides the bag into the sealer and removes the evacuator nozzle just prior to completion of sealing.

When the bag is fully sealed, the operator folds the top of the bag down onto the top of the inner carton and the carton and bag assembly is stamped and moved into position to be lifted by the load balancer. He clamps the load balancer onto the carton and bag assembly, lifts it, and lowers it onto the outer carton. After closing the outer carton, the operator seals it with a hand tape dispenser and stamps the carton. The carton is then pushed a few feet to the end of the roller conveyor where it is removed and relocated as desired by facility personnel.

All controls for packout are located on the equipment in the packout area. No controls (status lights) are provided in the control room. The packout design is arranged so that it can be segmented to accommodate almost any ARRADCOM arrangement of spacing and barrier walls. Final quantities of inspectors and operators must be established after equipment installation and will be based on equipment layout and worker skill, efficiency, and workload.

The original barrier bag design had a side opening and the sealed carton had to be slid into it sideways or else be turned onto its side and be placed into the bag sideways. Evaluation of this design indicated that the carton could not be slid easily into the bag by the operator and that turning a filled carton onto its side would be an unnecessarily strenuous task for the operator. As a result, the barrier bag was redesigned to open from the top, so that the carton would not have to be inverted by the operator.

Allen-Bradley Programmable Logic Controller (PLC)

A decision was made early in the program to replace the originally proposed mini-computer with an Allen-Bradley PLC. Since the PLC was to be used to replace relay logic, it appeared expeditious to also use the PLC's arithmetic capabilities to perform the functions required of the mini-computer. However, after several technical meetings, it was decided to use the Allen 1771 PLC series to

handle the prototype line. In addition to the normal arithmetic capabilities, this unit allows expanded memory capacity up to 12,000 words, expanded data up to 1,024 words, and online programming and editing while the PLC is in the run mode. The online editing facilitates easier system debug, and the expanded data allows more storage for arithmetic operations. Both these items are desirable and the 1771-L3 PLC was chosen.

The arithmetic capabilities of the PLC allow one to read the identity of the empty pallet at the empty-weigh station and to store the appropriate weight associated with the increment in that pallet. When this pallet reaches the final-weigh station and the identity is once again read, the PLC stores the filled-increment weight and calls up the empty weight stored for the same pallet. The subtraction is done within the PLC, and a good or bad weight output is generated depending upon the comparison of the powder weight in this increment and the value stored within the PLC.

A good weight allows the PLC logic to continue the operation of the station for an acceptable part, whereas, a reject would cause the station to reject the part. In addition to these operations, the PLC is also used to count rejects generated within each station. After a certain amount of consecutive rejects are obtained, the PLC shuts down the station. Additionally, counters are provided within the PLC to accumulate the total number of rejects generated within each station. These values will be preiodically tabulated on a separate printer.

For the full production system, it is planned to use two 1774-L3 PLC's. One PLC will control the six empty-weigh and final-weigh stations, as well as to perform all the arithmetic operations and to store the weight for the pallets. The other PLC will be used to control the propellant-weigh-and-fill stations, tab-seal stations, tab-check stations, and the reject-removal station.

Other Equipment Controls

All exposed switches in the stations are microswitch explosion-proof types rated for class I, division 1, group D, and class II, division 1, groups E, F, and G environments. The solenoids and power valves are also explosion-proof, meeting the same requirements as above, and are being provided by Numatics. The reliability of these controls is very high.

All cylinders on the system, with but few exceptions, are supplied by Miller or Schrader Company because of their efficient design, high reliability, and compact size. Reliability of prelubricated cylinders is less than lubricated cylinders, so lubricated cylinders are used to optimize the design MTBF. To optimize cylinder response time, it was necessary to locate the controlling power valves as close to the cylinders as practical.

Air gages and amplifiers provided by Walle Company monitor precise height gaging and position checking. They were selected because of their high accuracy, design simplicity, and high reliability. The amplified air outputs are supplied to air-operated microswitch switches located in explosion-proof junction boxes on the station. The electrical output from these switches is used as an input to the Allen-Bradley PLC.

Pinch valves provided by RKL Controls control propellant flow within the propellant-weigh-and-fill station. These were selected because they are made of conductive rubber and do not abrade the powder.

Photocells at the stations are intrinsically safe; use of Kent Barriers in light source and receiver lines provide the intrinsic safety characteristics required.

Pushbutton controls on the station are explosion-proof and are being used in explosion-proof boxes rated for the line environment. Manual station operation is controlled with these pushbuttons.

In the control room, pushbuttons are the Cutler-Hammer oil-tight series. The pushbuttons have long-life lamps, which are easily replaceable from the front of the switch, and they are a combination switch and indicator wherever possible.

Intec Force-Restoration Balance

The Intec Force-restoration balance is used in the empty-weigh station and the final-weigh station. The first balance was received in January 1978, along with manuals for operation and repair. The balance was electrically designed for the explosion-proof environment, and close work between ARRADCOM, Innova, and Intec resulted in a design which is considered inherently safe by ARRADCOM Safety Division. The force coil and linear variable differential transducer are potted and encased in stainless steel, and the wires are run in a stainless steel conduit that is filled with epoxy.

Acceptance testing of the balance at Intec and also at Innova indicates that the balance meets all accuracy and response requirements and that the unit is considered acceptable for use within our system. Use of this balance within the system requires vibration and wind currents be kept to a minimum and also that ferrous metals be kept 254 mm (10 in.) away from the scale force coil.

Since this ferrous material would create hysteresis effects and give erroneous weight readings, these factors were kept in consideration during design of the station. To accommodate the vibration requirements, the balance is mounted on its own separate platform and is completely isolated from the station.

The Intec balance has an adjustable integration time for weighing, and it can be set as low as 0.1 second. A part could be accurately weighed in that time if outside influences such as vibration, air currents, and inertia of part placement did not affect the reading. Under operating conditions, an integraion time of 0.5 second was selected for station design. This time is considered adequate to compensate for the influences discussed above. In addition to weighing the part, the complete cycle also includes a 0.5-second zero tare prior to each weighing, to set the balance to zero. This compensates for any particles on the balance or any variations due to wind or vibration, and allows for accurate weighing of the part.

Weighing Tolerance Analysis

Due to the nature of weighing devices, variations in external temperature cause corresponding variations in the weight readings. To determine the impact of these variations on the Intec balance used in the empty-weigh and final-weigh stations, a tolerance analysis was performed. The set of curves in figure 1 shows the probable percent rejection of good containers as a function of temperature variation assuming a straight line distribution of empty increment and powder fill weights.

The weighing tolerance analysis for the 60-mm and 81-mm line--including part tolerance, tab tolerance, powder tolerance, scale accuracy, and temperature variations--was submitted to ARRADCOM. At the empty-weigh station, with the assumption of the worst case straight-line distribution of the increment weights and a temperature variation of ±22.2°C (±40°F), 4.5% of good parts will be rejected. If the temperature is ±5.6°C (±10°F), the reject rate drops to 2.5%. As the distribution of weights approaches a mean and as less parts are near the tolerance limits, these percentages of rejects will decrease. In actuality, if no increments are within 9 milligrams of the tolerance limits, then there will be no rejected good parts, even with temperature variations of ±22.2°C (±40°F).

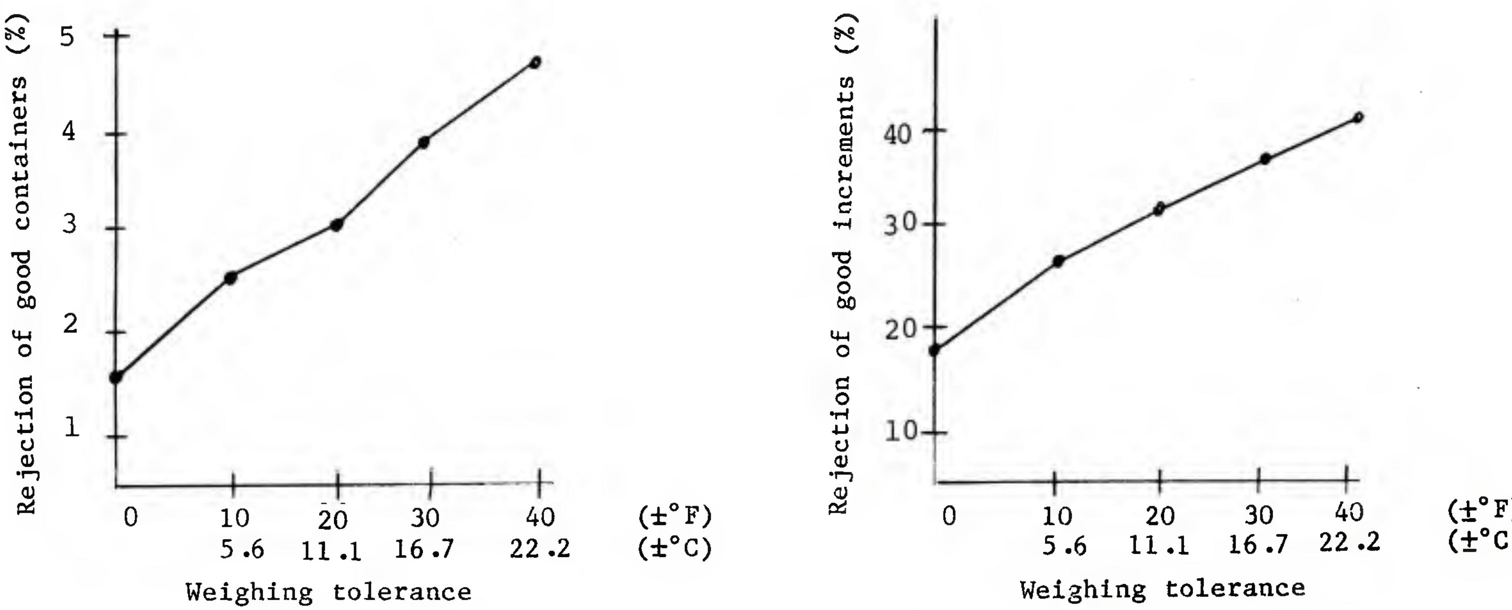
At the final-weigh station, however, temperature impact is more significant. With the 60-mm increments, a temperature of ±2.8°C (±5°F) results in the rejection of 21% of the good increments with a straight-line weight distribution for powder charges, whereas ±22.2°C (±40°F) results in 41% rejects. Once again, as the weight distribution of increments approaches the mean, and less charges are near the tolerance limits, these percentages of rejects will drop. At 2.8°C, if no charges are within 21 mg of the limits, no good parts will be rejected. At ±22.2°C, if no charges are within 40 mg of the limits, no good charges will be rejected. As the distribution widens, the rejects increase.

From this analysis, it is evident that as the weight distribution for increments and charges is tightened, temperature control for the line can be loosened. As weight distribution data becomes available, it will then be possible to determine the best temperature control limits for the system. At present, since the weight distribution parameters are not known, a temperature control variation of ±2.2°C (±4°F) was selected. This environmental control is not only desirable for the scale, but is also desirable for the increment and the propellant, both of which are affected by humidity. This tolerance will provide better environmental control conditions and better tolerances on the parts.

The Hi-Speed balance is also affected by changes in external temperature. However, after each weigh cycle, the balance automatically calibrates the balance and makes adjustments to compensate for any weight variation from the target weight. By this means the balance periodically compensates for inaccuracies due to temperature variation.

ARRADCOM Safety Tests Features

The results of safety tests performed by ARRADCOM on the increment and propellant are summarized below.



EMPTY-WEIGH STATION

FINAL-WEIGH STATION

Figure 1. Rejection of good containers and increments vs weigh station temperatures

The storing of approximately 2,000 filled and empty increments and some loose propellant in a reject bin 305 x 305 x 457 mm (12 x 12 x18 in.) high is acceptable. There were no test incidents, and the contents only burned.

In tests of initiating a loaded increment on a pallet, burning propagated, pallet to pallet. (The pallets butted one to another.) Propagation did not occur if the distance between increments was 254 mm (10 in.), center-to-center. It was decided by ARRADCOM that, in lieu of static shields, the propagation would be arrested solely by a quick-acting water deluge and sprinkler system (provided by MAAP). This guideline was followed in the system design.

A review by Innova of acetone used in the tab-seal station indicated that an estimated 10 drops of acetone would be required to seal each increment. Including evaporation, approximately 18.9 liters (5 gal) of acetone would be used to produce 40,000 increments in the 24-hour period. This quantity would produce an acetone vapor level in the proposed work area of about 8,000 PPM, but, since air changeover in a nonventilated room is estimated to occur once per hour, the acetone level would be substantially lower.

A subsequent analysis by ARRADCOM indicated that the acetone fumes released by this equipment would not present a hazard, and a central exhaust would be adequate to handle the fumes. However, a dedicated exhaust system was recommended to MAAP for each integral propellant-weigh-and-fill and tab-seal station. This recommendation was made because of the considerable amount of propellant and graphite dust which can be encountered with the Hi-Speed or Eriez Feeder systems, the closeness of the multiple propellant-weigh-and-fill and tab-seal stations at MAAP, and the type controls used.

Empty increments can be crushed, punctured, or drilled without initiation of the NC material. Filled increments can be dropped 1.5 x 2.1 meters (5 to 7 ft) with no ignition. If NC is held to a flame, it burns vigorously.

Tests were conducted on crushing of the propellant used in the increment (M10) and no incidents occurred. Tests involved dropping 3.6 kg (8 lb) weight on the propellant from a height of 254 mm (10 in.). Ten samples were tested. The filled container was not tested, because it is considered less sensitive to impact than M10 propellant alone.

No detonation of donor nor ignition of acceptor containers was encountered with fiber containers loaded with 2.3 kg (5 lb) of M10 propellant. These containers are to be used by MAAP in filling the upper hopper of the propellant-fill station.

Tests performed by ARRADCOM on propellant heights in excess of 76.2 mm (3 in.) in powder hoppers indicated that no ignition would occur if the outer OD-to-height ratio of the hopper is greater than 0.9. This guideline was followed in the design of the Hi-Speed system.

Packaged M204 or M205 propelling charges (1728 each and each, respectively, in fiberboard boxes) will only burn, not detonate, when ignited from the bottom.

A preliminary hazards analysis of the system design was conducted by the contractor. At the request of the Project Manager's Office (PMO), a separate and more detailed safety study and a hazards analysis of the design were conducted by Southwest Research Institute. The changes based on the results of both of these studies have been incorporated into the prototype line to a very great extent. All recommended safety features will be closely observed and modified as required; and any additional safety features deemed necessary will be incorporated, based on live M10 propellant runs at MAAP.

During the design and based on preliminary test runs, very much precaution has been taken to handle the increment in such a manner so as not to have it abraded or punctured, and to avoid the application of excessive forces which would result in NC dust or particles. During the preliminary acceptance tests and earlier debugging runs, no readily perceptable dust has been encountered on the nearly 10,000 increments run through the stations during the debugging stages.

The safety requirements of AR 385-100, National Electric Code, OSHA, etc., have been followed very closely in the design and build of this equipment. Wherever the increment or propellant can come in contact with the live material, nonsparking metals and conductive plastics or rubber have been used. All controls, motors, etc., are grounded, explosion-proof, purged, intrinsically safe, inherently safe, or removed from the live components and/or their environment.

The Intec scales have been designed to be inherently safe. All coils are potted and sealed in stainless steel cases, and the wires that come from these coils are run in a stainless steel conduit which is filled with epoxy. All items are terminated in an explosion-proof junction box within the balance.

The Hi-Speed feed system also meets all explosion-proof requirements except for the Eriez feeder and the transducers (manufactured by Transtek). The feeder is potted and epoxied, and this feeder, along with the Transtek transducers and the total feeder system, has been accepted by the Safety Division at ARRADCOM as being inherently safe.

Reliability and Maintainability Prediction

A reliability and maintainability prediction analysis was completed. The predicted MTBF of 7 hours exceeds the ARRADCOM specified minimum MTBF of 4.75 hours by almost 50 percent. Also, the predicted mean time to repair (MTTR) of 11.5 minutes is less than the ARRADCOM-specified 15 minutes, and all system failures are capable of being repaired in less than 1.5 hours. The reliability prediction of the system was based on the exponential distribution as outlined in MIL-STD-756A and MIL-HDBK-217B. Failure rate data was obtained from ARRADCOM, vendors, and military publications. The maintainability prediction was based on procedure 2 of MIL-HDBK-472. Average times to perform corrective maintenance tasks were based on military standards and Innova's past experience. System availability was based on the relationship of MTBF and the MTTR as evaluated by the reliability and maintainability prediction. Specific data is provided in the prediction analysis.

Human Factors Engineering

The human factors engineering plan was supplied to and approved by ARRADCOM early in the program and has been followed throughout the concept, design, and build phases of the program to achieve an effective integration of man into the design. This action resulted in the required effectiveness and personnel performance during system operation, maintenance, and control, and resulted in economical demands upon manpower, resources, skills, training, and costs.

Line Acceptance Test

Prelimimary line acceptance tests were conducted in July 1980 at Innova, Inc., Clearwater, FL. The results of these tests are as follows:

1. A summary of test critical values is shown in table 1. The station and system rates can be set differently from the machine or average rate shown in table 1.

2. The CV values attained by the stations and the system are relatively close to that established. More importantly, with minor adjustments and corrections of certain stations (namely, the empty- and final-weigh stations and the tab-seal stations), the equipment would readily meet and considerably exceed the prescribed CV's.

3. Stations had stoppages numerous times due to container dimensional deviations, lack of sufficient debugging, and station adjustment or correction time.

4. The reject removal and manual or visual tab-check stations (after one initial failure of the tab-check station) operated satisfactorily during the acceptance tests. CV calculations were not required.

The cause of the problems encountered was readily determined, and the required corrections are known. The equipment will be corrected by MAAP prior to shipment of the line. The test strongly indicates the need to improve the quality of the container, to comply with the current drawings and specifications. If the quality of the container can be improved (investigation currently underway), the tooling of certain stations could be improved.

CONCLUSIONS

The following conclusions are made:

1. The basic design of the system is sound, complies with all safety requirements, provides an efficient production control means, and has drastically reduced line personnel.

Table 1. Test critical values

Station	Parts per minute		Length of test (min)	Critical value* obtained	Critical value* required	Requirement obtained (%)
	Machine rate	Test rate				
Empty-weigh	26.3	28.3	30	0.660	0.713	92
Powder-weigh-and-fill	4.3	4.8	30	0.686	0.713	96
Tab-seal	8.0	4.8	30	0.631	0.713	88
Final-weigh	26.3	7.5	30	0.662	0.713	93
Overall system	4.3	4.8	240	0.376	0.429	87

*Critical value (CV) is defined as the total number of acceptable (N) items divided by the product of the production rate (R) of the station or system and the length of time (T) of test run, or CV = N/RT.

2. The equipment can be readily modified to accommodate possible container production deviations and future design changes.

3. In the final acceptance test conducted with inert propellant, the individual stations reached 88 to 93% of the critical values set forth by the PMO. The overall system reached 87% of these critical values. Minimal changes are required to meet the prescribed requirements to give this line production capabilities.

RECOMMENDATIONS

The following recommendations are made:

1. The prototype line should be installed at MAAP and used for the loading and assembly of the mortar increments.

2. The system should be duplicated and used by other loading plants engaged in the LAP of mortar increments.

3. To enhance the prototype system and make it more suitable for production use, the prototype line should be modified in accordance with the improved design features shown below.

a. Empty-Weigh Station and Final-Weigh Station - The finger extensions should be modified to accommodate the increased thickness of the flange seam on the containers which were used in the acceptance test. This modification can be incorporated with a minimum of effort, but it is highly desirable due to the observed dimensional nonconformities of the increments. Design modifications which will reduce the magnitude of the backlash due to vibrations should be incorporated.

b. Propellant-Weigh-and-Fill Station - The fill station cycle time is the highest of any of the individual station cycle times on the system. A program to conduct a comprehensive sequence of tests to determine the influence of operational parameters such as pressure pulse magnitude and duration, pulse-on to pulse-off time ratio, and jet nozzle geometry is recommended. The experimental investigation should provide sensitivity type information which could result in design modifications to the fill station geometry and result in operational aspects which could reduce the duration of the powder-fill cycle.

c. Tab-Seal Station - The seal station as currently configured exhibits some tendency to build up dissolved and resolidified NC material on the tab pickup foot. There is also exhibited a tendency of the tab to become slightly skewed as it is wet and placed by this foot. Redesign of the tab foot to incorporate edge guides and a material change to a teflon or similar substance are expected to result in markedly improved reliability of function at this station.

d. Reject-Removal Station - Element ejection from the reject-removal station results in ejection of the rejected increment at significant velocities. Combinations of eductor exit baffle and sleeve arrangements and reject bin impact-absorption features can be investigated to mitigate damage of rejected empty or filled increments.

e. Intec Scales - The Intec scale is an integral part of the empty- and final-weigh stations. Problems observed in the operation of the Intec balance originate with mechanical vibration, elecrical interference, feedback, coulomb damping, flexural support, and other causes. The sensitivity of the balance to these effects should be investigated.

f. Air-Type Sensors - The air-type sensors have exhibited tendencies to malfunction when sensor parts or lines become plugged with debris and when the air amplifiers became contaminated with very small quantities of water, oil, or particulate matter which is not removed from the air supply system. Operation of both the stations and the system will be improved by replacement of the air-type sensors with the electro-optical sensors used for many logic functions. There are currently 37 air-type sensors in the system and it is recommended that they all be replaced.

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